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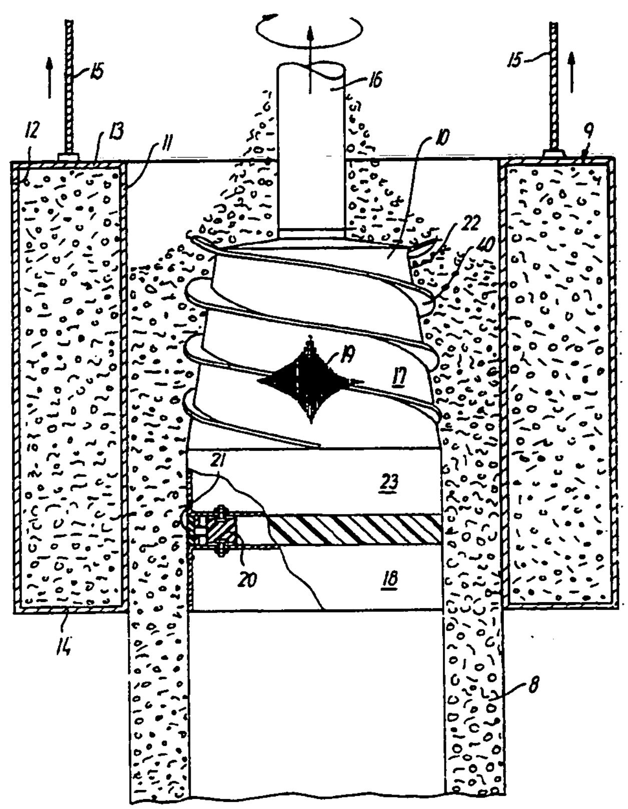
(57) Abstract

A slip-form machine serves to cast hollow bodies, in particular pipes of concrete or a similar material, substantially vertically by means of successively progressing zonewise vibration compression. The machine comprises inner and outer slip-form mould parts (9, 10), respectively, which are displaced axially with respect to each other during the casting process. The inner mould part (10) is divided into at least two sections (17, 18) interconnected via one or more elastic spacers, and the uppermost one (17) of these contains at least one vibrator. The natural frequencies of the outer mould part (9) are significantly different from the frequency of the vibrations which are generated by the vibrator. By means of the abovementioned structure it is now possible to cast e.g. concrete pipes in a faster working cycle, with much smaller investments in moulds, and with a smaller energy consumption than known before. The pipe moreover has a completely uniform quality in the longitudinal direction as well as along the periphery and can be cast with much narrower longitudinal and diameter tolerances than before.



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A machine for casting hollow bodies, in particular concrete pipes, and comprising two mutually axially movable slip-form mould parts

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The invention concerns a slip-form machine for casting hollow objects, in particular pipes of concrete or a similar material, substantially vertically by means of successively progressive zonewise vibration compression, comprising inner and outer slip-form mould parts, respectively, which are slidingly displaced along the already cast part of the hollow object during the casting process, the inner mould part being divided into at least two sections interconnected via one or more elastic spacers, the uppermost one of said sections containing at least one vibrator.

Traditionally, casting of e.g. concrete pipes takes place by filling the ring gap between an inner and an outer stationary mould part from above with fresh concrete which is continuously vibrated. The vibrations are generated by one or more vibrators, which are usually positioned in the inner mould part, from which the vibrations spread to the outer mould part via the concrete. The vibrator must therefore have a sufficiently great capacity to be able to subject the relatively great vibrating mass of the concrete as well as of the entire mould system to correspondingly great acceleration forces. Furthermore, the vibrator must be capable of providing the energy which the vibrating system consumes, and which is just partly utilized in the actual vibration compression process, since a considerable part of the added energy is instead converted to heat and very trying noise in the actual mould system. In practice, the overall great mass of the system, which is thus to be accelerated repeatedly in rapidly changing directions, limits the possibility of

working with sufficiently high vibration frequencies for optimum achievement of the liquidity in the concrete which is necessary for effective compression of it.

Since the mass of the vibration system is not constant, but, on the contrary, constantly changes as the mould is filled with concrete, the vibration state of the system will vary greatly during casting. Nor is the concrete vibrated throughout for the same length of time, it being kept in a vibrating state for a longer time downwardly in the mould than upwardly. These conditions in combination entail that the concrete is subjected to a process which varies in dependence on the level of the concrete in the mould, and that the finished pipe therefore cannot be made with the desired uniform and well-defined quality throughout in the longitudinal direction.

In a further development of the above-mentioned method, with a view to obtaining a better result, the vibrator is positioned right at the top of the inner mould part, and the two mould parts are displaced axially with respect to each other during casting. This displacement can take place e.g. in that the outer mould part is stationary, while the inner mould part continuously rises from below up into the outer mould part, while the mould is simultaneously successively filled with so much fresh concrete that a specific layer of concrete is constantly disposed around the area of the top of the mould part where the vibrator is present. This layer, which moves upwardly in the mould together with the rise of the inner mould part, will substantially be in the same state of vibration in all the levels of the mould and will moreover be vibrated for the same period of time, so that the vibration compression process can be controlled better and the finished pipe can have a more uniform quality in the longitudinal direction.

However, the previously mentioned drawbacks associated with casting in stationary mould parts are not eliminated completely. The reason is that the vibrations propagate from the top down through the inner mould part and thereby still bring the concrete into vibration states, which depend on the level of the concrete in the mould, during the course of the overall casting process, just as, in this case too, the concrete is vibrated for a longer time downwardly in the mould than upwardly. Nor is it therefore possible by means of this improved method to cast a concrete pipe which fully satisfies the requirements which are today made with respect to a well-defined high and uniform quality of a concrete pipe throughout its overall length.

This, however, has been made possible to perfection by means of the machine described in the applicant's Danish Patent Application, DK xxxx/91, "A machine for casting hollow objects, in particular concrete pipes, and comprising two mutually axially movable mould parts", which has the same filing date as the present application and is incorporated herein by reference. This machine differs from the previously known machines of this type in particular in that the inner mould part is divided into two sections which are mutually separated by a spacer, thereby effectively restricting the vibration of the concrete to an axially narrow zone around the uppermost section, and providing a hollow object or pipe which has a perfect uniform quality in the longitudinal direction.

However, as is the case with the above-mentioned previously known methods, it is still a problem to keep the diameter tolerances within the desired limits, because the hollow object or the pipe tends to settle to a certain degree during the demoulding operation, where the mould parts are removed in their full length by the just

deposited and not yet set concrete, which has a relatively poor stability of shape in this state. At any rate as regards the inner mould part the demoulding process takes place in the actual mould machine, which is therefore occupied for this purpose for a not insignificant part of the total possible operating time. Moreover, the method requires huge investments in the many moulds which a manufacturer with a reasonably great range of goods must necessarily have in store, because a set of associated mould parts can only be used for a specific diameter and a specific length, and because the tools themselves are moreover very expensive since both mould parts must at least have the same length as the cast hollow body or pipe.

The object of the invention is to provide a machine of the type mentioned in the opening paragraph, which, with a minimum energy consumption for the vibration compression process and relatively modest investments in moulds, is capable of making a great range of cast hollow objects, in particular concrete pipes, within a shorter working cycle than before, which have a perfect uniform quality throughout the longitudinal direction, and which also carefully observes the prescribed tolerances longiditudinally as well as transversely.

This is achieved by the machine of the invention which is novel and unique in that the natural frequencies of the outer mould parts are significantly different from the frequency of the vibrations which are generated by the vibrator. When e.g. concrete pipes are slip-form cast the cast part of the pipe is exposed as the two mould parts are displaced upwardly during the casting process. The concrete in the exposed pipe part has now been carefully compressed, and the pipe part is therefore sufficiently strong to support its own weigth without settling or

collapsing, but not to withstand further loads of importance from external forces. It is therefore necessary that the vibrations in the vibration compression process, which still takes place closely above the exposed pipe part, will have no possibility at all of propagating to it.

The above-mentioned significant differences between the vibration frequency and the natural frequencies of the outer mould part ensure effectively that the vibrations generated by the vibrator are not transmitted to the outer mould part via the concrete. At the same time the elastic suspension of the lower section of the inner mould part from the upper section of the mould part ensures that the vibrations are not transmitted from the upper to the lower section either, and a concrete zone positioned between the outer mould part and the lower section of the inner mould part will therefore be provided immediately above the exposed pipe part, said concrete zone being at complete rest and therefore serving as a vibration insulation for the underlying exposed pipe part, which does not receive vibrations of any type either from the mould parts which directly adjoin the pipe part.

As mentioned, the inner mould part is elastically suspended from the upper section of the mould part, and it is therefore present in a labile state in itself, in which it is not capable of absorbing transverse forces. However, the lower section is nevertheless kept safely in place in the transverse direction by the outer mould part via the compressed quiet concrete in the zone between the outer mould part and the lower section of the inner mould part. Immediately above this zone the concrete is kept in a form of liquid state by the vibrations, so that the concrete is distributed evenly and uniformly along the periphery. Therefore, during the continued upward displacement of the

mould parts the concrete will enter the underlying quiet concrete zone and ensure that the lower section of the inner mould part is constantly kept in a position concentric with the outer mould part, so that the wall thickness of the finished pipe is completely uniform along the periphery.

As appears from the foregoing, because of the special inventive coupling between the various parts of the mould system and between these and the various concrete zones it is now possible to slip-form cast e.g. concrete pipes to perfection which carefully observe the prescribed diameter tolerances. The pipe is calibrated directly during the actual casting process to a precise dimension by the lower section of the inner mould part, and the dimension thus calibrated is maintained completely in the finished pipe, because this is demoulded concurrently with the casting and is therefore not subjected to deformations because of a subsequent demoulding operation like in the past. This demoulding operation is now obviated completely, thereby also providing the advantage that the overall operating time is reduced correspondingly. Another advantage achieved by means of the arrangement of the invention is that the investments in moulds are considerably smaller than before, because a set of moulds can now be used for all pipes with the same diameter, irrespective of the length.

The intended natural frequencies of the outer mould part can be achieved in various ways. In an advantageous embodiment the outer mould part may thus be built as a sheet iron structure which has natural frequencies in itself that differ significantly from the vibration frequency. This structure may in turn be provided with a heavy mass of e.g. concrete, which imparts natural frequencies to the overall outer mould which are so much

below the vibration frequency that the outer mould cannot keep up with the applied rapid vibrations and therefore remains standing in a quiet state. In principle, the outer mould part may therefore be suspended freely from e.g. wires or be rigidly suspended from machine parts, whose mass then contributes to determining the natural frequency of the outer mould part to a certain extent.

As is the case with the machine described in the applicant's above-mentioned Danish patent application DK xxxx/91, it is just the relatively small mass of an axially narrow zone around the position of the vibrator in the uppermost section which is affected by the vibration forces. The energy supply to the system can therefore be reduced drastically with respect to the conventional technique. When the overall system consisting of the casting mould and the concrete is arranged as an absorber system with the casting mould as the main system and the concrete as the subsystem in the manner described in the applicant's Danish Patent Application, DK xxxx/91, "An absorber system for casting hollow objects, in particular concrete pipes, by means of vibration compression", which has the same filing date as the present patent application and which is incorporated herein by reference, the supply of energy can essentially be reduced to comprising just the energy which is consumed for vibrating the concrete.

During the mutual axial displacement between the two mould parts, the narrow vibration zone successively travels upwardly with respect to the casting mould and is subjected to quite the same vibration effect in all of its levels, while the already deposited and vibration compressed concrete is kept at rest by the lowermost section of the inner mould part. Since the concrete is therefore subjected to the same process throughout the casting mould, it will consequently now also be possible to make

concrete pipes which have a completely uniform and well-defined high quality in the entire longitudinal extent of the pipe.

The vibrations entail that the concrete is brought into a form of liquid compressible state. The volume of the concrete is reduced during the compression, and in the prior art this causes vertical transport of material to take place in the ring gap between the two mould parts, so that filling of the mould and the compression of the concrete are impeded significantly because of the friction between the concrete and the mould parts. To avoid this transport of material and the consequent drawbacks the uppermost section of the inner mould part has an upper conical portion with a conicity which downwardly narrows the cross sectional area of the ring gap between the conical portion and the inner side of the outer mould part in a proportion which is substantially inversely proportional to the increase in density which the compression simultaneously imparts to the concrete during the relative axial displacement between the two mould parts.

Compression of the concrete requires that the concrete is loaded with a suitable static pressure, which conventionally just consists of the weight of the overlying column of concrete. However, loading of the narrow vibration zone, which does not have any greater amount of concrete disposed thereover is relatively small, and, according to an advantageous embodiment of the invention, the inner mould part is therefore suspended rotatably, and the conical portion of the upper section is equipped with a generally multi-thread screw, which serves to transport the concrete downwardly and to simultaneously apply to the concrete a predetermined downwardly directed static pressure during the compression process, which can thus be controlled optimally by means of a suitable selection of

the pitch of the convolutions and the speed of rotation of the inner mould part.

When the spigot end on a concrete pipe is to be cast, a profile ring is usually employed, having the same nominal inside diameter as the pipe. For the spigot end to be cast in immediate continuation of the pipe shank, the convolutions are dimensioned with an outside diameter which is throughout at least slightly smaller than the inside diameter of the profile ring opening, so that the uppermost section can pass upwardly through this opening during the final phase of the casting.

Since the vibration zone is axially relatively narrow, and since it is intended to restrict the vibrations to this narrow zone, a rotating vibrator is used, imparting rotating horizontal vibrations to the uppermost section. In a particularly advantageous embodiment another type of vibrator is used, imparting horizontal vibrations to the uppermost section with directions of deflection which lie in a predetermined fixed plane through the axis of the section. This additionally reduces the amount of concrete which vibrates, and since the deflection plane follows the rotation of the section it is simultaneously ensured that the concrete is vibration-compressed completely uniformly around the periphery of the pipe.

To effectively ensure that the part of the hollow object or the concrete pipe which is successively exposed during the casting process, is in no way subjected to vibrating impacts, the machine of the invention has been given a pattern of motion where the mould parts are displaced such that the lower edge of the part of the outer mould part which contacts the already cast part of the hollow body or the concrete pipe, is constantly at a lower level than partly the actual vibrated zone of the concrete, partly

the upper edge of the lowermost section of the inner mould part after said section has contacted the concrete.

The machine of the invention lends itself to casting of hollow objects or concrete pipes having a cross-section which is uniform or varies longitudinally. Thus, concrete pipes are generally provided with a socket at one end and a spigot at the other which mates with the socket of an adjoining pipe. Therefore, the two mould parts of the machine do not always move together during the casting process, the machine having a pattern of motion where the mould parts are mutually displaced upwardly in dependence on the cross-sectional shape which is desired in each individual case in a specific casting level.

The uppermost section of the inner mould part moreover has a cylindrical portion which is in continuation of the conical portion, and which, by a intermediate elastic sealing ring, is continued by the lower, likewise cylindrical section of the mould part. When the inner mould part rotates during the casting process, the cylindrical portion of it acts as a trowel that smooths the concrete and imparts a tight and smooth inside surface to the finished pipe.

In addition to the above-mentioned smoothing, it is frequently necessary to improve the inside surface of the finished pipe additionally. For this purpose a surface improving material is pumped via a pipe connection out through at least one opening in the uppermost section. When this rotates with simultaneous mutual axial displacement of the two mould parts, this opening describes a screw line, whereby the surface improving material is applied to or incorporated in the concrete surface evenly and uniformly. Examples of useful surface improving materials include fine concrete, plastics or water.

With a view to measuring the compression quality of the deposited concrete a sensor is arranged in the uppermost section. This also describes a screw line during the rotation of the section and therefore successively passes all areas of the deposited mass of concrete, which can thus be detected completely. The vibration compression process can be optimized by adjusting one or more of the parameters comprising the relative displacement speed between the mould parts, the rotational speed of the uppermost section and the vibration frequency and/or vibration amplitude. These parameters are then controlled by means of the signal from the sensor such that the desired density of the concrete is kept constant during the entire casting process.

The invention will be explained more fully by the following description of embodiments which just serve as examples, with reference to the drawing, in which

fig. 1 shows a set of mould parts for normal casting of concrete pipes with stationary or mutually displaceable mould parts,

fig. 2 shows a set of mould parts for slip-form casting,

fig. 3 shows the slip-form mould parts of fig. 2 suspended in a casting machine,

fig. 4 is an enlarged, partly sectional view of a concrete pipe being cast by means of the set of slip-form mould parts shown in fig. 2,

figs. 5a-p are partial axial sectional views of various stages in the casting of a concrete pipe with a socket end and a spigot end by means of a set of slip-form mould parts and an upper profile ring firmly arranged in the

outer mould part for shaping the spigot end,

figs. 6a-p are partial axial sectional views of various stages in the casting of a concrete pipe with a socket end and a spigot end by means of a set of slip-form mould parts and a freely displaceable upper profile ring for shaping the spigot end,

fig. 7 is a side view of the top of a rotating inner mould part according to the invention with incorporated sensor,

fig. 8 shows the same, but in a partial axial section, where the sensor is clearly visible,

fig. 9 is a side view of the top of an inner mould part according to the invention with the outer wall partly removed so that a pipe connection to a surface improving material is visible, and

fig. 10 shows the same, but in a partial axial section.

Fig. 1 shows a set of mould parts 1, 2, which may be for traditional casting of concrete pipes with stationary mould parts, or for casting with displaceable mould parts, as described e.g. in the applicant's Danish Patent Application xxxx/91. In any event, the mould parts must have a length at least equal to the finished pipe, and it is moreover usually necessary to provide a separate set of mould parts for each pipe length within a specific dimension. These casting methods therefore require huge investments in moulds, if the concrete product manufacturer is to be capable of producing and supplying a reasonably great range of goods.

In contrast, the set of slip-form mould parts 3, 4 shown in fig. 2 is relatively short and therefore inexpensive

and the overall investments in moulds are reduced additionally to a significant degree, because a set of mould parts can be used for pipes in all lengths, provided that the pipes have the same diameter and are otherwise shaped in the same manner at the ends, e.g. with uniform socket and spigot ends. Further, the slip-form mould parts facilitate handling and transport of the moulds, as well as switching from one pipe length to another within a specific diameter, because such switching now does not require laborious exchange of the mould parts, but merely quick and simple adjustment of the casting length of the machine.

Fig. 3 shows the set of mould parts 3, 4 of fig. 2 suspended in a casting machine which is generally designated 6. By comparison with the person 7 standing at the side of the machine it is possible to get a certain impression of the frequently considerable size of the cast pipes and the savings which can be obtained using slip-form casting because of the considerable reduction in the length of the mould and the simultaneous reduction in the number of moulds which the concrete product manufacturer has to have at his disposal to be able to supply a sufficiently great range of goods. In the shown case the mould parts are displaced upwardly during casting and finally leave the finished and demoulded pipes standing on a bottom ring, ready for being transported to a curing site by means of e.g. a fork truck. However, instead of raising the mould parts 3, 4, the slip-form casting can also take place by lowering the pipe with respect to the mould parts, which will therefore just have to be displaced mutually to the extent necessary for casting the socket and spigot ends of the pipe.

Fig. 4 shows on an enlarged scale how a concrete pipe 8 is cast by means of an outer slip-form mould part 9 and an

inner slip-form mould part 10. The outer mould part 9 is built as a sheet iron structure with internal and external shells 11, 12 which are connected with upper and lower plate rings 13, 14. This structure per se has a natural frequency which is either considerably greater or considerably smaller than the vibration frequency. The cavity of the structure is filled with concrete which, together with the iron structure, imparts such a great overall mass to the outer mould part that the natural frequency of the mould part will be much below the vibration frequency. This entails that the outer mould part is not brought into vibrations even though the concrete vibrates, but that the mould part will instead remain in a quiet state, such that it just has to be hoisted vertically upwards suspended from wires 15 during the casting process. However, as shown in fig. 3, the outer mould part may be rigidly suspended from an axially displaceable machine part which is associated with the machine 6, and which will thereby contribute to the overall mass of the outer mould part to a certain degree. Likewise, other materials than concrete may be used for filling the cavity of the sheet iron structure. Thus, lead may advantageously be used for limiting the outer diameter of the mould part, or a liquid such as water or oil which can be drained when the mould part is to be transported or be stored for an extended period of time.

The inner mould part 10 is suspended from an axially displaceable machine part 16 and is divided into an upper section 17 and a lower section 18. The upper section 17 moreover contains a vibrator (not shown), the vibrations themselves being indicated by the symbol 19. The lower section 18 is suspended from the upper section 17 by means of a plurality of elastic spacers, which are rubber buffers 20 in the shown case, but may also suitably be springs. The gap between the two sections 17, 18 is

outwardly sealed with a sealing ring 21 of e.g. rubber or an elastic plastics material.

Casting of the concrete pipe 8 now takes place by filling fresh concrete into the ring gap between the two mould parts 9, 11 as these are displaced upwardly in the direction indicated by the arrows. The vibrator is constantly activated during this, as indicated by the symbol 19, and the vibrator thereby vibrates the upper section 17, said section in turn bringing the surrounding concrete into vibrations. As mentioned before, the vibrations are not capable of propagating out to the outer mould part 9 because of the great difference between the natural frequencies of said outer mould part and the vibration frequency, and the outer mould part will therefore hang quietly in the wires 15, while it is successively displaced vertically upwardly during the casting process. Since the lower section 18 of the inner mould part is suspended in a vibration-insulated manner from the vibrating upper section 17, the lower section of the inner mould part will be in a quiet state during the casting process like the entire outer mould part, so that the concrete zone interposed between these mould parts 18, 9 is kept completely free of vibrations. The underlying exposed part of the cast pipe is therefore not subjected to any form of vibration pulses and can therefore stand freely without being deformed during the successive demoulding, which finally leaves a finished pipe standing in the casting machine. The inside and outside diameters of this pipe, which are determined by the outer mould part 9 and the lower section 18 of the inner mould part 10, are maintained completely in the finished pipe, which is not deformed by subsequent demoulding operations like before. The concrete pipes can therefore be cast with an unprecedented uniformity and precision in the transverse direction.

However, the lower section 18 of the inner mould part 10, which calibrates the pipe interiorly, cannot absorb transverse forces owing to its elastic suspension from the rubber buffers 20 and therefore cannot by itself assume a position concentric with the outer mould part 9. However, this is ensured according to the invention by the outer mould part, which stably supports the inner mould part via the intermediate quiet concrete zone, which was formed as a concentric ring already during the immediately preceding vibration compression, in which the concrete was in a form of liquid state, said ring being sufficiently strong, because of the compression, to be capable of transmitting transverse forces between the outer mould part 9 and the lower section 18 of the inner mould part 10.

Said coupling between the outer mould part and the lower section of the inner mould part via the intermediate ring of quiet, compressed concrete is of fundamental importance for the making of the desired perfect pipes by the described slip-form casting. In this connection it is moreover important that the intermediate concrete ring, which constitutes the uppermost, but not yet exposed portion of the pipe part finished at a given time, has concentrically extending inner and outer sides. The shape of the concrete ring is determined already during the immediately preceding vibration compression process in the overlying zone between the outer mould part and the upper section, where the concrete is in an almost liquid state. However, for the concrete ring to become concentric, it is necessary that the outer mould part and the upper section are constantly concentrically positioned with respect to each other during the casting process, i.e. have the same axis which simultaneously defines the axis of the pipe. The position of the outer mould part is determined, as explained previously, and when the inner mould part is of the non-rotatable type, the correct coaxial position of

the upper section can be ensured by means of a sufficiently rigid suspension in the casting machine, so that the axis of the upper section, force controlled, will coinside with the defined pipe axis during the vertical displacement of the inner mould part. Such forced control is not necessary when the inner mould part rotates during the casting process. In that case the inner mould part may be suspended from e.g. a vertical rod which is sufficiently dimensioned to transmit the necessary torsional moment to overcome the frictional forces between the inner mould part and the concrete without, however, being capable of absorbing major transverse forces. The upper section will then automatically move into a natural central position, in which the resulting impact on the section from the friction against the concrete and from the "liquid pressure" of the concrete is zero. In this structure the outer mould part is given a natural vibration frequency which, in addition to being significantly different from the vibration frequency, is preferably considerably lower than the number of revolutions of the inner mould part, such that the outer mould part is not vibrated because of the rotation of the inner mould part.

In the case shown in fig. 4, the lower edge of the outer mould part is flush with the lower edge of the lower section. However, during the axial upward displacement of the mould parts, the two lower edges can extend in any other manner with respect to each other, but the lower edge of the outer mould part must never be in the immediate vicinity of or above the upper edge of the lower section or at the same level as the actual, vibrated zone of the concrete. This would entail that the lower section would no longer be duly supported by the outer mould part, and that moreover there would no quiet, vibration-insulating concrete zone above the exposed pipe, which

would therefore be deformed or collapse.

In the same manner as described in the applicant's previously mentioned Danish Patent Application DK xxxx/91, only a narrow concrete zone around the upper section is brought into vibrations at a given time. Owing to the highly reduced mass of this zone it is now possible to use a vibrator which has a much smaller capacity than the vibrators used in conventional machines of this type. When the overall system, which consists of casting mould, mechanical fixing parts and concrete, is additionally adapted as an absorber system with the casting mould as the main system and the concrete as the subsystem in the manner described in the applicant's Danish Patent Application No. xxxx/91, "An absorber system for casting hollow objects, in particular concrete pipes, by means of vibration compression", which has the same filing date as the present application and is incorporated herein by reference, the supply of energy to the system can essentially be restricted to just comprising the energy necessary for vibrating the narrow zone of concrete around the upper section.

The small mass of this zone with respect to the mass of the overall system enables the use of much higher vibration frequencies than before, whereby the intended liquidity in the concrete is obtained optimally. When the concrete is in this state, it can easily be compressed, thereby reducing its volume and correspondingly increasing its density. To prevent this reduction in volume from causing vertical transport of material in the relatively narrow ring gap between the two mould parts, which would lead to an energy-consuming friction which would also impede the free course of the casting process in an adverse manner, the upper section 17 is provided with an upper conical portion 22 whose conicity is adapted such

that the cross sectional area of the ring gap is narrowed downwardly in a proportion which is inversely proportional to the increase in density which the compression simultaneously imparts to the concrete during the relative axial displacement between the two mould parts.

For the compression to take place, the concrete, as explained above, must be brought into a liquid state by the vibrations, and the concrete must be affected by a vertical static pressure which is usually provided by the weight of the overlying column of concrete. However, this column is usually relatively low, and the static pressure on the concrete is therefore small and also varies greatly with just small changes in the filling rate. In the arrangement shown in fig. 4, the inner mould part 10 can therefore be caused to rotate during casting in the direction shown by the arrow, and the conical portion 22 of the upper section is moreover provided with preferably several convolutions which, at a specific speed of rotation, apply to the concrete a predetermined downwardly directed pressure which is considerably greater than the pressure from the overlying concrete column. This pressure can be regulated by changing the speed of rotation and by means of a suitable selection of the pitch of the convolutions. It has been found that the optimum pressure impact on the concrete can be obtained best when this pitch is relatively small and when there are several convolutions which together form a multi-thread screw.

The conical portion 22 of the upper section 7 downwardly merges into a cylindrical portion 23, which, via the elastic sealing ring 21, continues in the lower section 18 which, as mentioned before, i.a. serves to calibrate the pipe interiorly, but which also serves as a trowel smoothing the surface of the concrete during the rotation of the inner mould part. If the height of the lower

section 18 is too low, the calibration will be incomplete, since it can then partly take place in the transition zone to the not yet finish-compressed concrete, and if the cylindrical portion is too high, too great friction forces can easily occur between the portion and the concrete, which is thereby affected by a torque which can entail deformation in the pipe. The best solution to these conflicting conditions is that the height of the lower section 18 is between 0.1-1.0, preferably between 0.3-0.7 and in particular between 0.4-0.6 times the diameter of the portion.

Figs. 5a-p show various stages in the slip-form casting of a concrete pipe 24, said pipe being in this case provided with a socket 25 and a spigot 26. The outer part is indicated by the reference numeral 27 and the inner mould part by the reference numeral 28. The outer mould part 27 is suspended from wires 29 in the same manner as the outer mould 9 shown in fig. 4, but it may also be suspended from a rigid, but vertically displaceable machine part, as shown in fig. 3. A profile ring 30 for shaping the spigot end 26 is firmly mounted upwardly in the outer mould part 27, and a filling hopper 31 is in turn mounted on top of the profile ring. Downwardly, the outer mould part has an inside expansion 33, which corresponds to the outer side of the pipe socket 25, and which, together with a bottom ring 32 for supporting the cast pipe 24, serves to shape the pipe socket 25. The inner mould part 28, which is arranged in the same manner as the inner mould part 10 shown in fig. 4, is suspended from a vertically slidable and simultaneously rotatable machine part (not shown) by means of a rod 34.

In order to be able to cast the pipe 24 with the socket 35 and the spigot end 26, the machine must be adapted such that the mould parts 27, 28 has a quite specific pattern

of motion during the casting process, which depends on the specific shape of the pipe in each individual case.

In fig. 5a the mould parts 27, 28 are present in their starting positions in which the lower end of the outer mould part contacts or is positioned in the immediate vicinity of the bottom ring 32, and the inner mould part 28 is in the opening of the bottom ring with the conical portion positioned slightly above the upper side of the bottom ring. The mould is thus closed downwardly and can therefore be filled with concrete, as shown in figs. 5b, c and d, the position of the outer mould part being unchanged, while the inner mould part, which now rotates and simultaneously vibrates, is displaced upwardly during casting of the socket 25. In fig. 5e the shank of the pipe is cast, the outer mould part now following the continued upward displacement of the inner mould part, until the outer mould part has reached its upper casting position in fig. 5f, in which the shank of the pipe is finished by and large, and casting of the spigot end is to begin. Figs. 5g, h and i show how the spigot end is cast, while the outer mould part stands still and the inner mould part continues its upward displacement through the opening of the profile ring until the mould part has emerged completely from the opening in fig. 5i. The concrete in the area of difficult access just below the profile ring is compressed during this by the multi-thread screw on the conical portion of the inner mould part, and the excess concrete is collected in a compressed state in the filling hopper 31. The pipe is now finished, and then the vibrator is stopped, as shown in fig. 5j, while the outer mould part is displaced upwardly, as shown in fig. 5k, until both mould parts have reached the position shown in fig. 5l in which the finished pipe stands freely on the bottom ring 32, which then serves as a pallet for transporting the pipe by means e.g. a fork truck to a curing site,

where the pipe remains standing on the bottom ring until it has set sufficiently. In fig. 5m the pipe is removed, and a new bottom ring is placed in the machine in fig. 5n. In fig. 5o the mould parts are on their way down to their starting positions, which are shown in fig. 5p, where the mould is now ready for a new working cycle. The return of the mould part to the starting positions can take place in a rapid movement, if desired, so that the time it takes to produce a pipe can be reduced correspondingly.

The casting process shown in figs. 6a-p substantially corresponds to the one shown in figs. 5a-p, and the same reference numerals are therefore used for the same parts. However, the upper profile ring is not correspondingly firmly mounted in the outer mould part, but instead suspended freely from a vertically slidable machine part (not shown). Figs. 6a-f show how the casting of the socket and shank of the pipe takes place by means of exactly the same pattern of motion as is shown in figs. 5a-f, which will therefore not be described more fully again. In fig. 6f the upper profile ring 35 is already on its way to the position shown in figs. 6g, h and i in which the spigot end 26 is cast in the same manner as shown in figs. 5g, h and i. In fig. 6j the pipe is finished and the vibrator is turned off. In figs. 6k and l the pipe is now completely demoulded, both mould parts being displaced upwardly until they are completely free of the cast pipe. However, the profile ring 35 remains standing and therefore advantageously serves as a back stop preventing the cast pipe from being carried completely or partly upwardly by the mould parts during the demoulding operation. In fig. 6m the profile ring 35 is now being pulled up, and in fig. 6n this operation is completed, and then the cast pipe 24 is ready for collection on the bottom ring 32. When the finished pipe has been removed, a new bottom ring is placed in the machine, and the mould parts are lowered to

their starting positions, following which the next working cycle can be initiated. Figs. 6o and p show a variant of the casting process in which a reinforcement 36 is placed on the bottom ring 32 before the mould parts are returned to their starting positions. This reinforcement will then be embedded in the pipe during the subsequent working cycle, which takes place in quite the same manner as described above.

For the spigot end of the pipe to be cast and compressed in the manner described above, the inner mould part 28 must be capable of passing the opening of the profile ring 30; 35, and the convolutions of the mould part must therefore have an outside diameter which is slightly smaller than the diameter of this opening.

The vibrator used may be a rotating vibrator, which rotates in the same or opposite direction of the inner mould part. The vibrations take place with a frequency of between 50 and 250 Hz, and the inner mould part rotates at a rate of up to 200 rotations per minute. Instead of a rotating vibrator, it is possible to use a vibrator which just brings the uppermost section of the inner mould part into horizontal vibrations with directions of deflection which lie in a fixed plane through the axis of the inner mould part, and which therefore rotate with the same speed of rotation as this mould part. When this vibrator type is used, the mass of the concrete amount subjected to vibrations at a given moment is additionally reduced to a significant degree with the consequent advantages in the form of e.g. reduced energy consumption.

The optimum vibration compression conditions which are capable of keeping the density of the concrete at the desired level during the entire casting process, can be provided by adjusting one or more of the parameters, the

relative speed of displacement between the mould parts, the speed of rotation of the inner mould part, as well as the frequency and/or amplitude of the vibrations. These parameters are controlled by a preprogrammed computer in response to the signals from a sensor 37, which is positioned in the upper section 17, as shown in figs. 7 and 8. The sensor may e.g. be adapted to measure the rate of an ultrasonic pulse during the passage to and fro through the wall of the cast pipe to the inner side of the outer mould part 9 (fig. 8), and the sensor system is then to be constructed as a transceiver system measuring the time delay of the reflected signal from the outer mould part. It will be seen from fig. 7 how the sensor 37 describes a screw line because of the simultaneous rotation and rise of the inner mould part 10. The wall of the cast concrete pipe is hereby inspected completely in its entire extent, and the mentioned ultrasound rate can be used as a measure of the quality of the compression by comparison with reference values known in advance, and the quality of the compression can thus not only be registered passively, but also be controlled actively if desired. For this purpose not only ultrasound sensors may be used, but also other suitable forms of sensors, e.g. X-ray sensors.

Figs. 9 and 10 show a pipe connection 38 which terminates in an outlet opening 39 in the upper section 17. The pipe connection 38 is connected with a reservoir (not shown) of a surface improving material, which can thereby be conveyed to the outlet opening 39 by means of e.g. a pump (not shown). This describes a screw line in the same manner as shown in fig. 7 for the sensor 37, and the surface improving material will therefore be applied completely uniformly over the internal surface of the concrete pipe, where it is additionally smoothed by means of the lower section 18 of the inner mould part 10. The surface improving material may be fine concrete or

plastics which settles as a thin layer on top of the concrete, or e.g. just water which brings the outermost surface of the concrete into a liquid state which can easily be smoothed to an even and tight layer.

As appears from the foregoing, the machine of the invention now makes it possible to cast e.g. a concrete pipe in a shorter working cycle, with much smaller investments in moulds, and with a smaller energy consumption than known before. The machine ensures that the cast pipe has a completely uniform quality both in the longitudinal direction and along the periphery, and that the pipe can be cast with much narrower longitudinal and diameter tolerances than before. Because of the described control system the process is moreover self-adjusting, such that a uniform quality is ensured from pipe to pipe in series of a desired size. To this should be added that the process can be switched easily and quickly from one quality to another by changing the production parameters via the control system. Correspondingly, within the same diameter, it is now immediately possible to switch from production of one pipe length to another merely by changing the casting length of the machine.

Although embodiments of the machine according to the invention for production of cylindrical pipes have been described above and shown in the drawing, other embodiments of the machine are readily conceivable within the scope of the invention, and such other embodiments may e.g. be adapted to cast pipes which are four-sided or six-sided exteriorly. Correspondingly, for the casting there may conceivably be used other materials, which are suitable for casting by means of vibration compression, than concrete e.g. the material described in the Danish Patent Application 1175/89, "A method of making acid-proof sulphur concrete pipes".

P a t e n t C l a i m s:

1. A slip-form machine for casting hollow objects, in particular pipes of concrete or a similar material, substantially vertically by means of successively progressing zonewise vibration compression, comprising inner and outer slip-form mould parts, respectively, which are slidingly displaced along the already cast part of the hollow object during the casting process, the inner mould part being divided into at least two sections interconnected via one or more elastic spacers, the uppermost one of said sections containing at least one vibrator, c h a r a c t e r i z e d in that the natural frequencies of the outer mould part are significantly different from the frequency of the vibrations which are generated by the vibrator.

2. A slip-form machine according to claim 1, c h a r a c t e r i z e d in that the outer mould part is built as a plate structure consisting of e.g. iron and having natural frequencies which are significantly different from the vibration frequencies, and that the plate structure is firmly connected with a mass of e.g. concrete which, together with the mass of the plate structure, imparts a natural frequency to the entire outer mould which is significantly smaller than the vibration frequencies.

3. A slip-form machine according to claim 1 or 2, c h a r a c t e r i z e d in that the machine has a pattern of motion where the mould parts are so displaced during the casting process that the lower edge of the portion of the outer mould part which contacts the already cast part of the hollow object is constantly at a lower level than the actual, vibrated zone of the concrete.

4. A slip-form machine according to claim 1, 2 or 3, c h a r a c t e r i z e d in that the machine has a pattern of motion where the mould parts are so displaced during the casting process that the lower edge of the portion of the outer mould part which contacts the already cast part of the hollow object is constantly at a lower level than the upper edge of the lowermost section of the inner mould part after said section has contacted the concrete.

5. A slip-form machine according to one or more of claims 1-4, wherein the hollow object is a pipe with a socket and a spigot end, and the inside contour of the socket is shaped by means of a bottom ring which also serves to support the pipe, c h a r a c t e r i z e d in that the machine has a pattern of motion where the mould parts are so displaced during casting of the socket that the outer mould part is in its starting position, while the inner mould part is displaced up through the opening of the bottom ring until at least the upper edge of the lowermost section has reached the level of the upper termination of the socket, and then the outer mould part follows the further upward displacement of the inner mould part.

6. A slip-form machine according to one or more of claims 1-5, wherein the hollow object is a pipe with a socket and a spigot end, c h a r a c t e r i z e d in that the machine has a pattern of motion where the mould parts are displaced upwardly at the same speed during casting of the shank of the pipe until the outer mould part has reached its upper casting position, and then the displacement of the outer mould part is stopped, while the displacement of the inner mould part continues upwardly.

7. A slip-form machine according to one or more of claims 1-6, wherein the hollow object is a pipe with a socket and

a spigot end, which is formed by means of a profile ring, c h a r a c t e r i z e d in that the machine has a pattern of motion where the outer mould ring is in its upper casting position during casting of the spigot end, while the inner mould part is displaced up through the opening of the profile ring until it is free of the cast pipe.

8. A slip-form machine according to one or more of claims 1-7, wherein the hollow object is a pipe with a socket and a spigot end, which is formed by means of a profile ring firmly connected with the outer mould part, c h a r a c t e r i z e d in that the machine has a pattern of motion where the mould parts are displaced upwardly during demoulding of the finished pipe until both of them are free of the pipe.

9. A slip-form machine according to one or more of claims 1-7, wherein the hollow object is a pipe with a socket and a spigot end, c h a r a c t e r i z e d in that the spigot end is formed by means of a profile ring which is freely suspended from an axially displaceable machine part, and that the machine has a pattern of motion where the mould parts are displaced upwardly during demoulding, while the profile ring is in its casting position, until both mould parts are free of the pipe, and then also the profile ring is displaced upwardly until it is free of the pipe.

10. A slip-form machine according to one or more of claims 1-9, c h a r a c t e r i z e d in that the uppermost section of the inner mould part has a lower cylindrical portion and an upper conical portion with a conicity which downwardly narrows the cross-sectional area of the ring gap between the conical portion and the inner side of the outer mould part in a proportion which is

substantially inversely proportional to the increase in density which the compression simultaneously imparts to the concrete during the relative axial displacement between the two mould parts.

11. A slip-form machine according to one or more of claims 1-10, c h a r a c t e r i z e d in that the diameter of the lower section of the inner mould part corresponds to the desired inside diameter of the cast pipe.

12. A slip-form machine according to one or more of claims 1-11, c h a r a c t e r i z e d in that the height of the lower section of the inner mould part is between 0.1-1.0, preferably between 0.3-0.7, and in particular between 0.4-0.6 times the diameter of the portion.

13. A slip-form machine according to one or more of claims 1-12, c h a r a c t e r i z e d in that the inner mould part is rotatably suspended, and that the conical portion is equipped with at least one convolution.

14. A slip-form machine according to one or more of claims 1-13, c h a r a c t e r i z e d in that the outside diameter of the convolution is equal to or slightly smaller than the diameter of the cylindrical portion.

15. A machine according to one or more of claims 1-14, c h a r a c t e r i z e d in that the inner mould part is formed with at least one outlet opening, which communicates via a pipe connection or the like with a pressure source for feeding a surface improving material, such as fine concrete, plastics or water, to the outlet opening.

16. A machine according to one or more of claims 1-15,

c h a r a c t e r i z e d in that a sensor for measuring the density of the concrete is provided in the inner mould part.

17. A machine according to claim 16, c h a r a c t e r i z e d in that one or more of the parameters, the relative displacement speed between the mould parts, the speed of rotation of the inner mould part, as well as the vibration frequency and/or vibration amplitude are controlled by means of the signal from the sensor such that the desired density of the concrete is kept constant during the entire casting process.

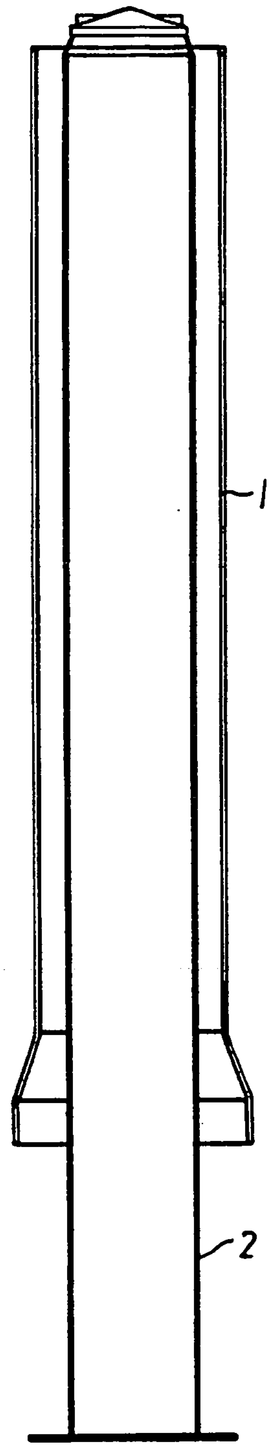

FIG.1

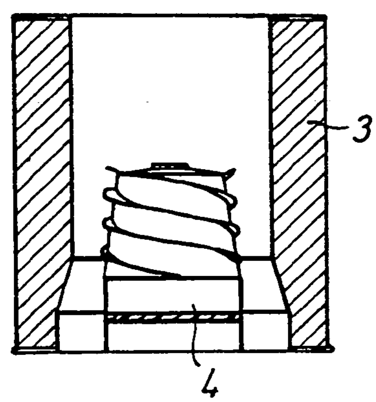

FIG.2

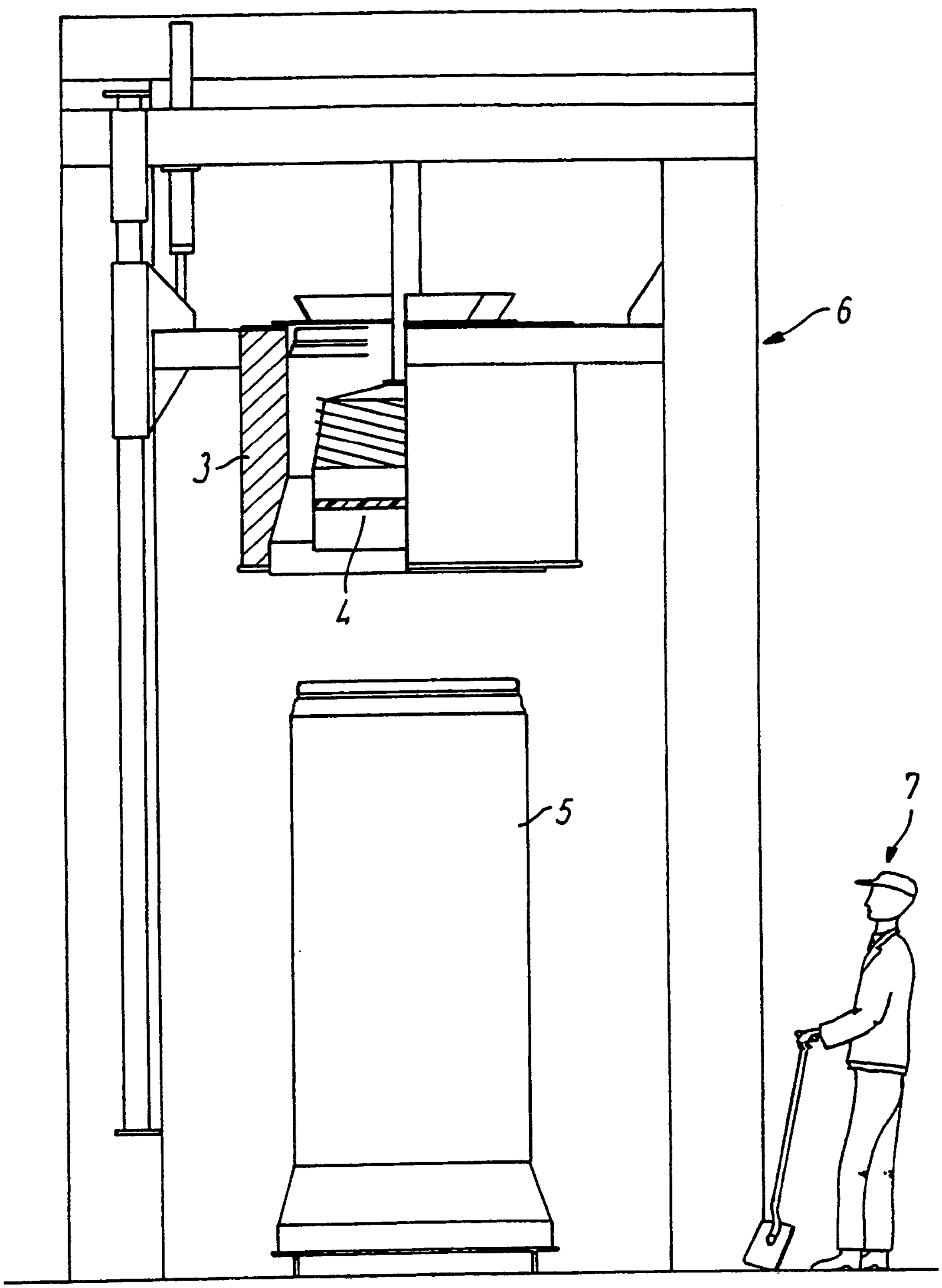

FIG.3

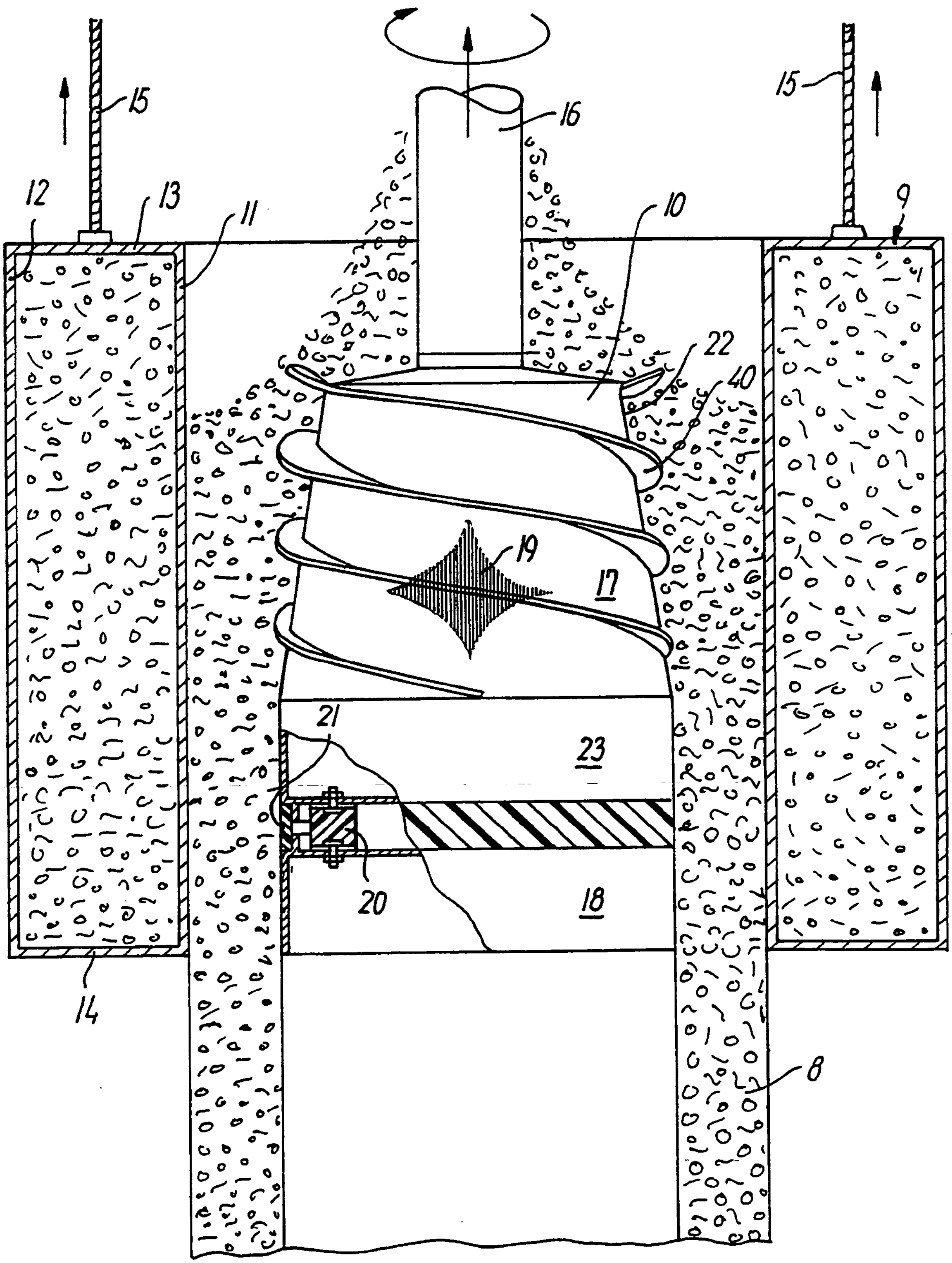

FIG. 4

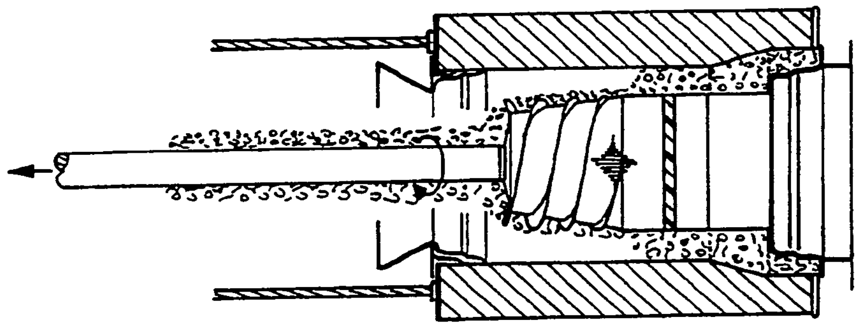

FIG.5d

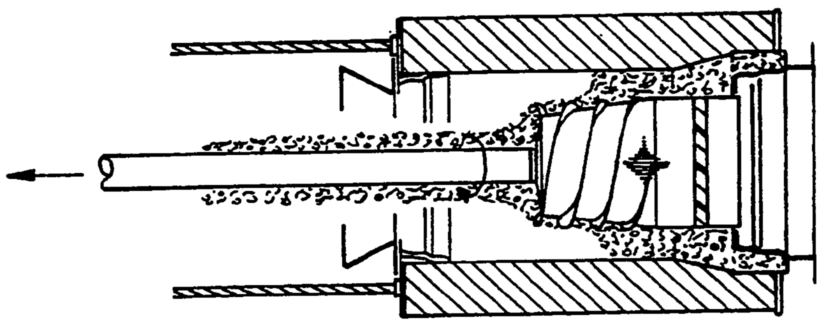

FIG.5c

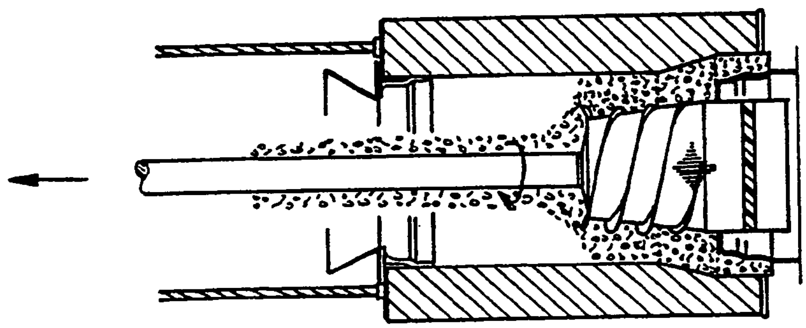

FIG.5b

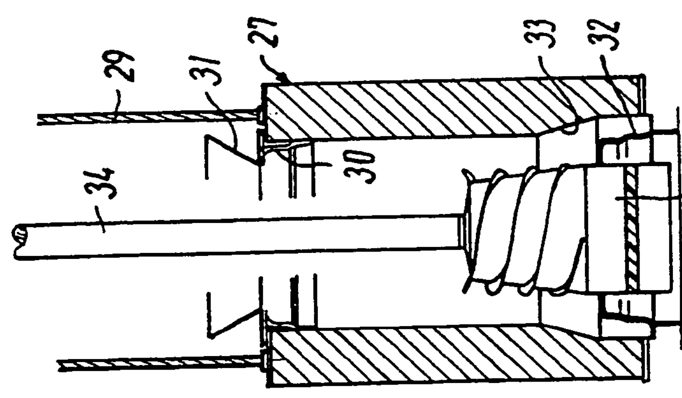

FIG.5a

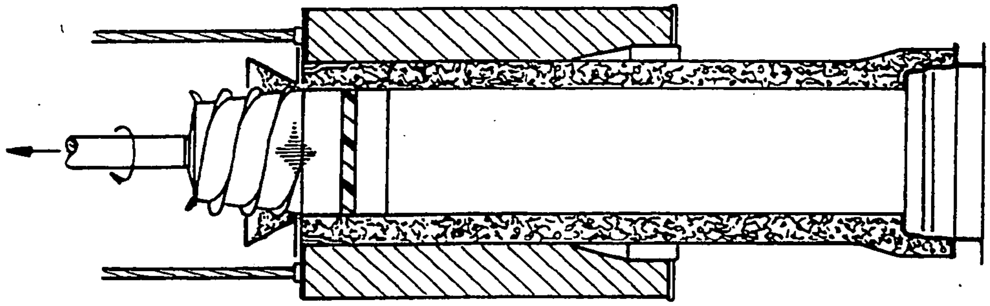

FIG.5h

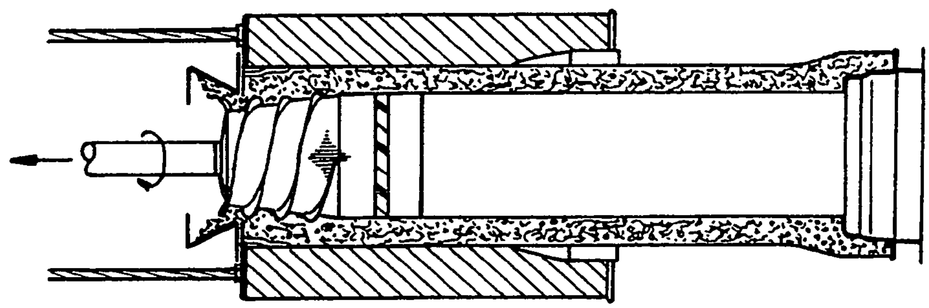

FIG.5g

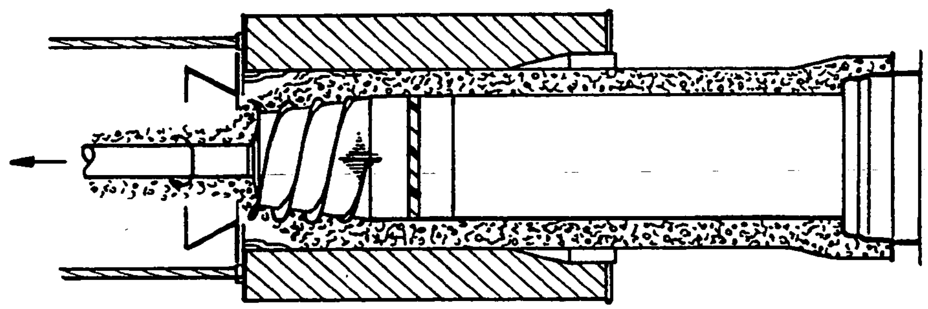

FIG.5f

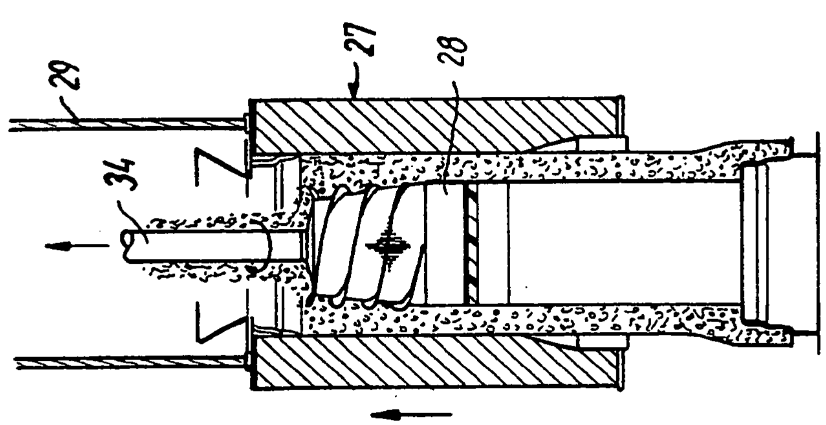

FIG.5e

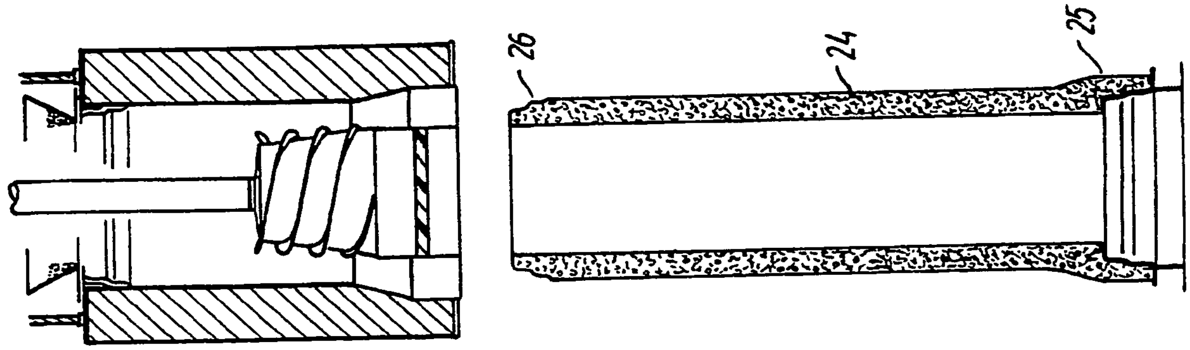

FIG.5l

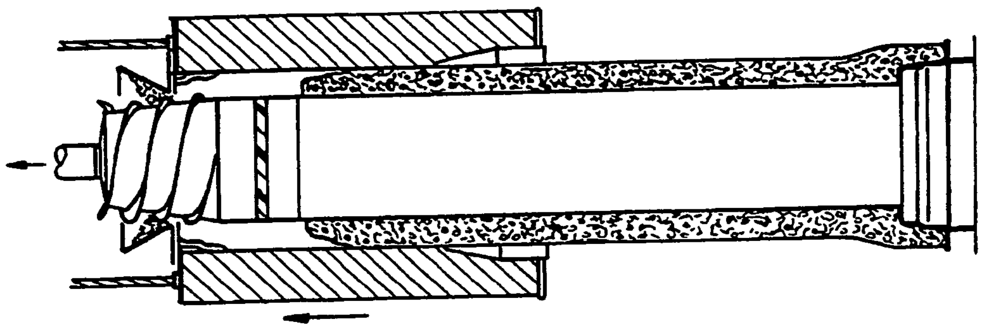

FIG.5k

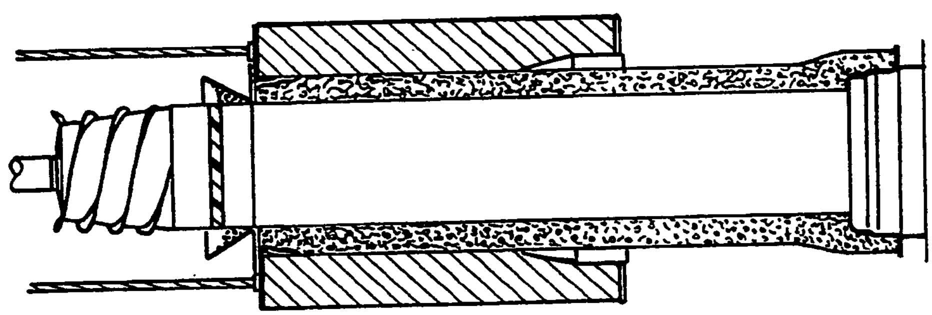

FIG.5j

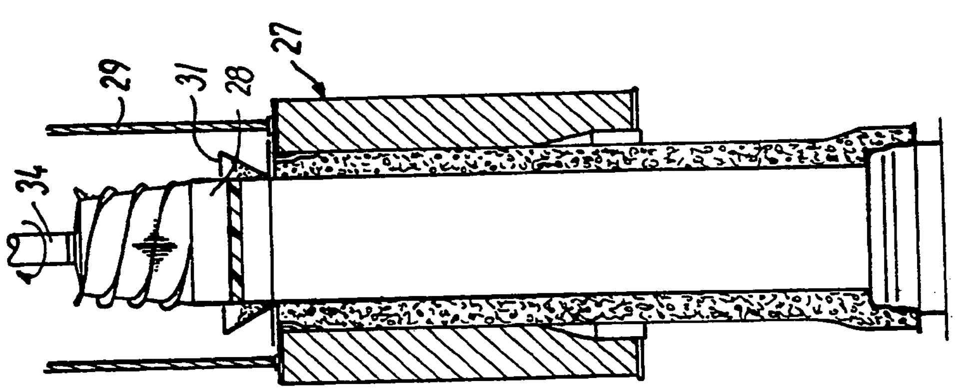

FIG.5i

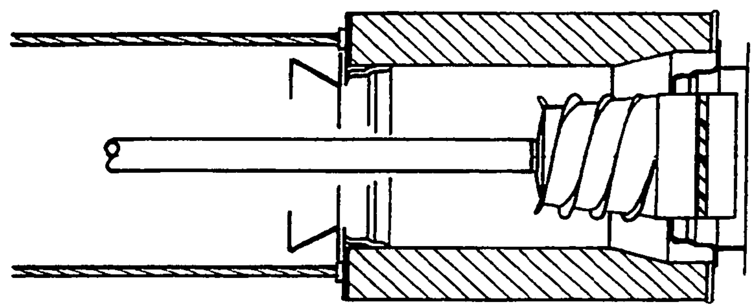

FIG.5p

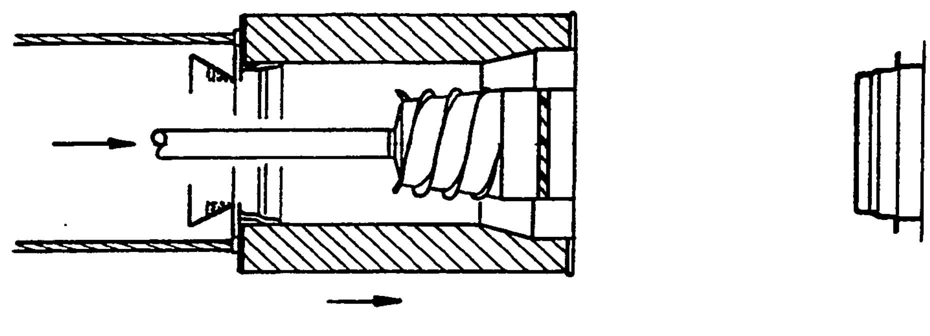

FIG.5o

FIG.5n

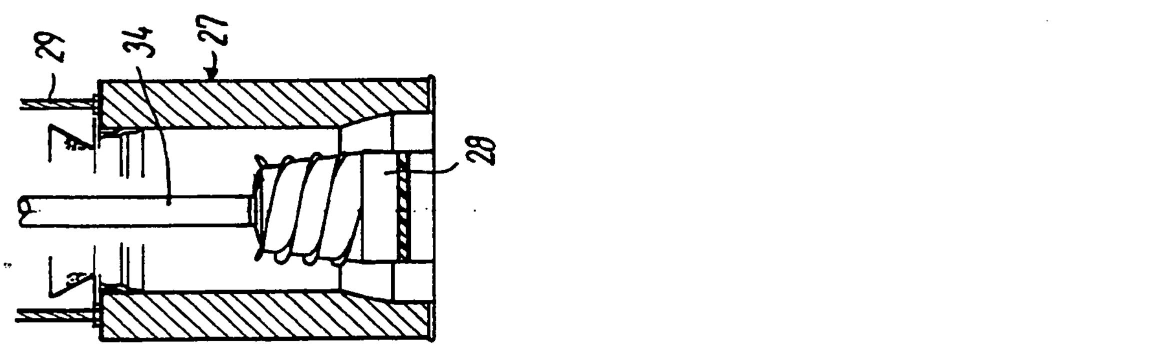

FIG.5m

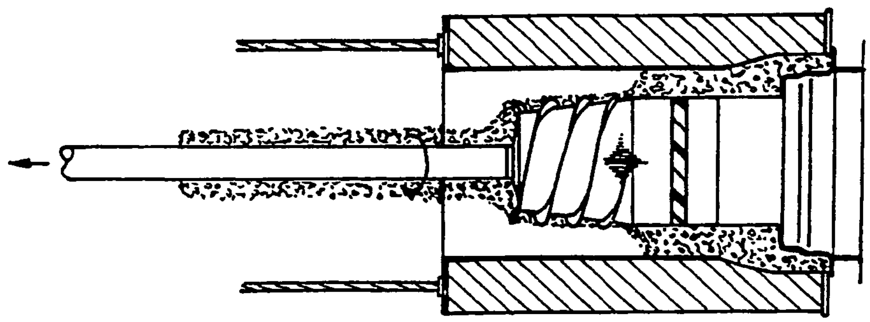

FIG.6d

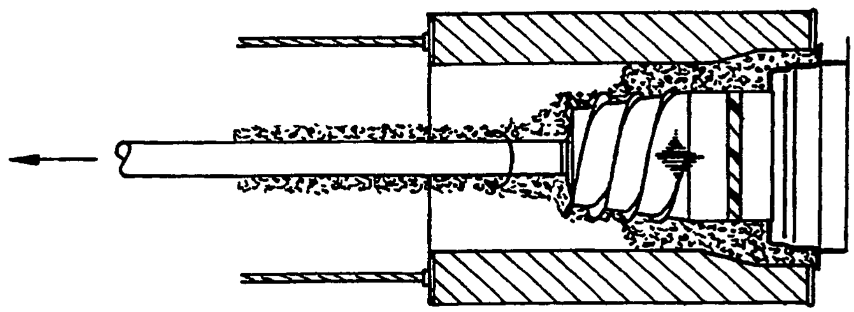

FIG.6c

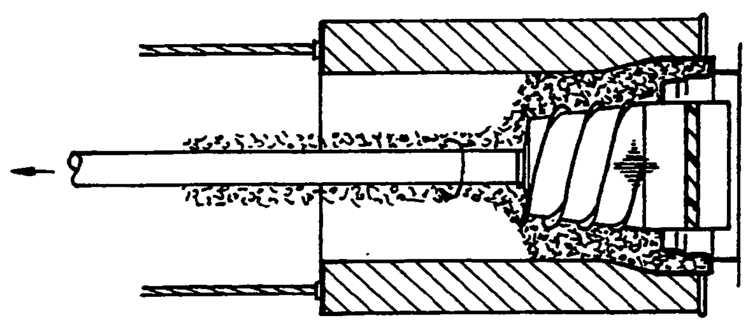

FIG.6b

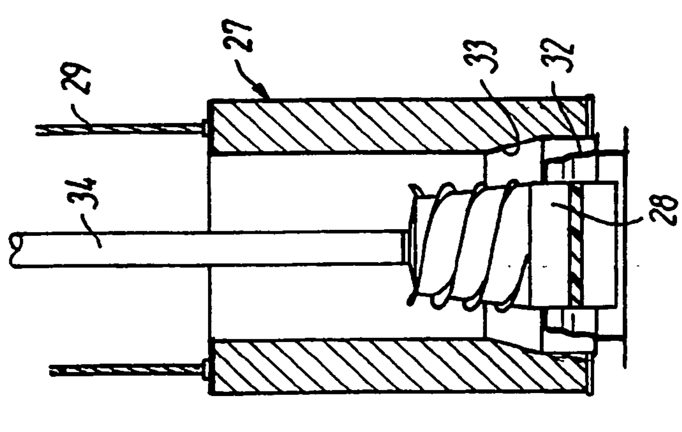

FIG.6a

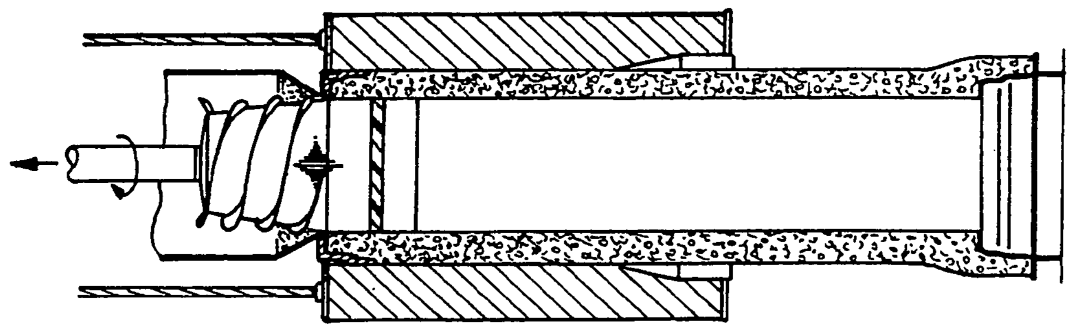

FIG.6h

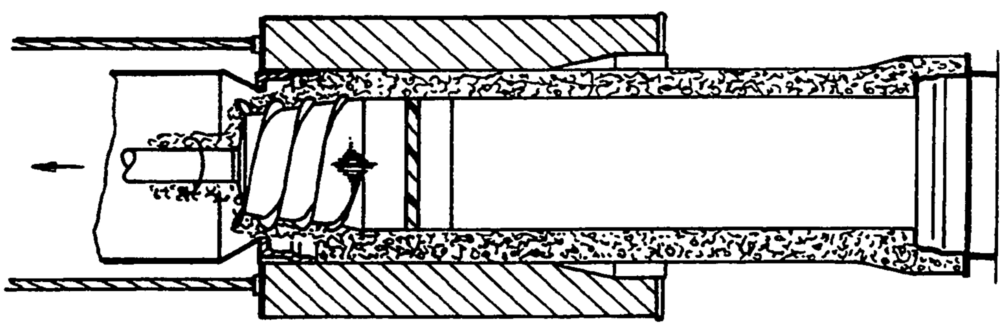

FIG.6g

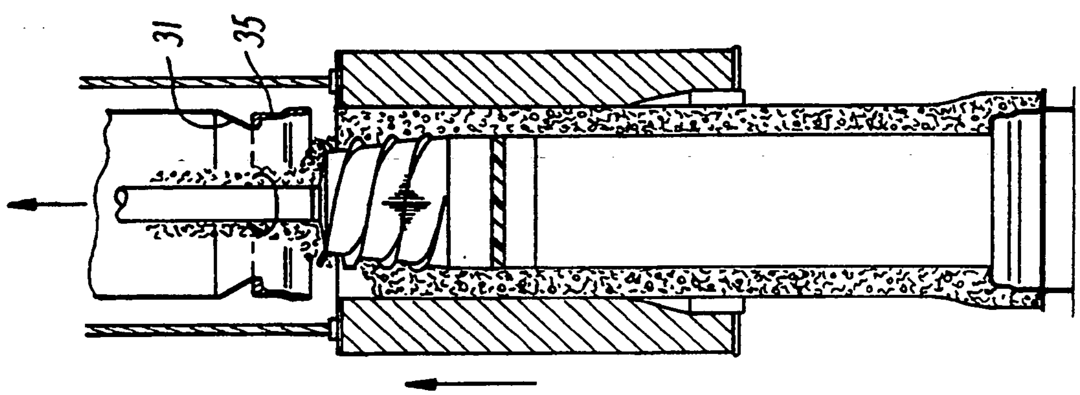

FIG.6f

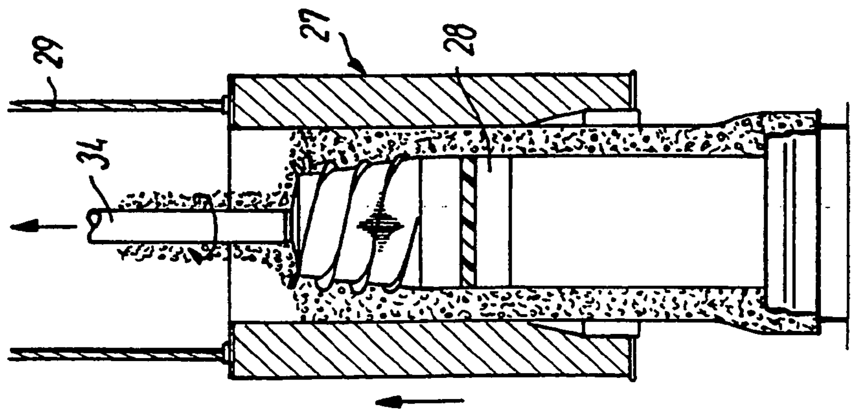

FIG.6e

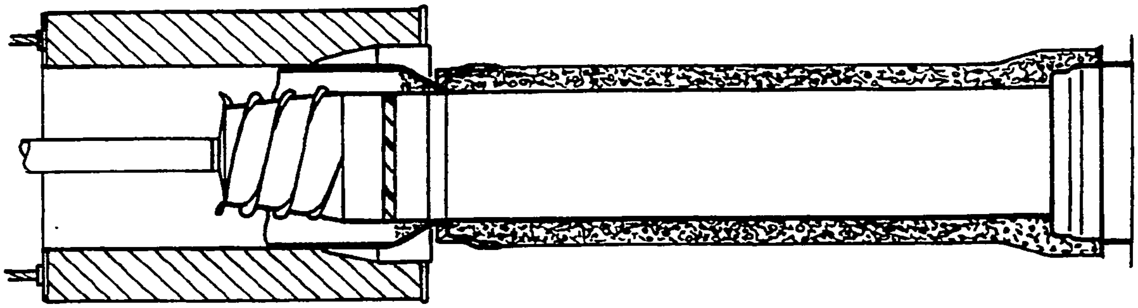

FIG.6l

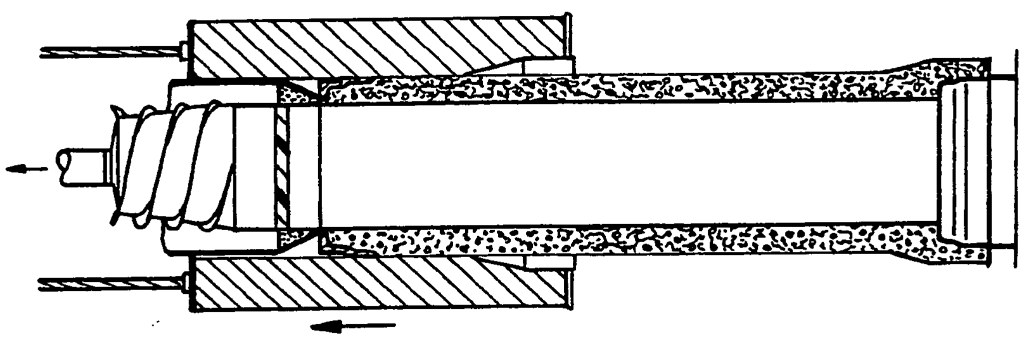

FIG.6k

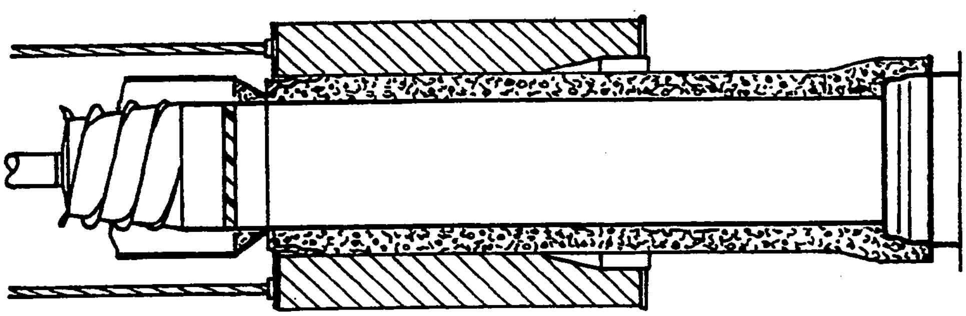

FIG.6j

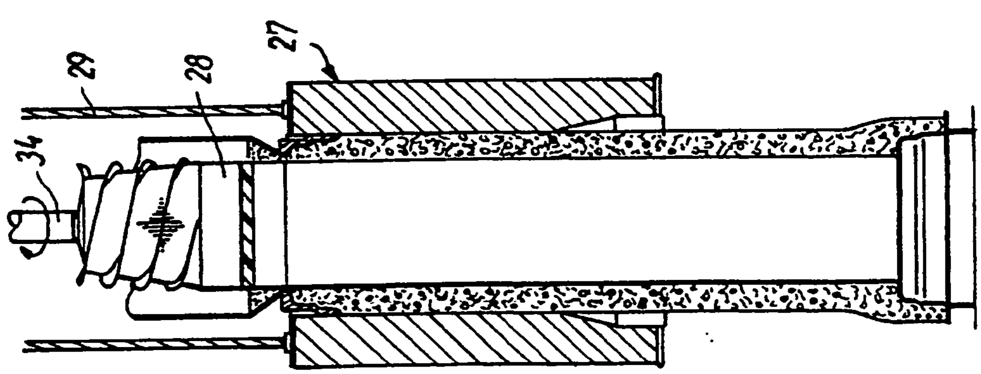

FIG.6i

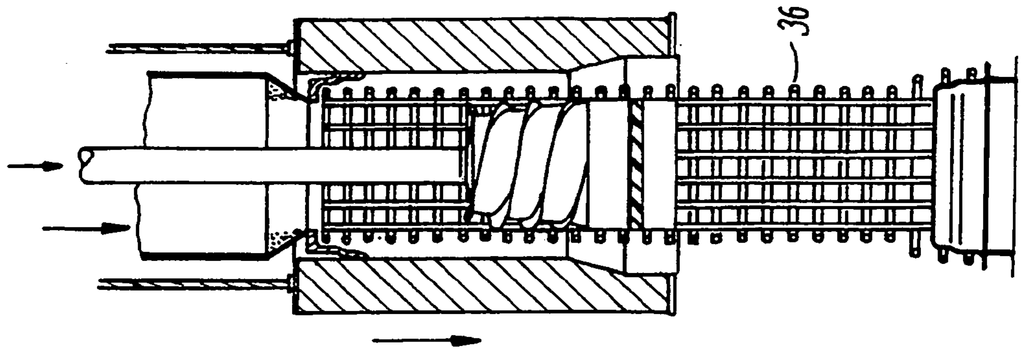

FIG.6p

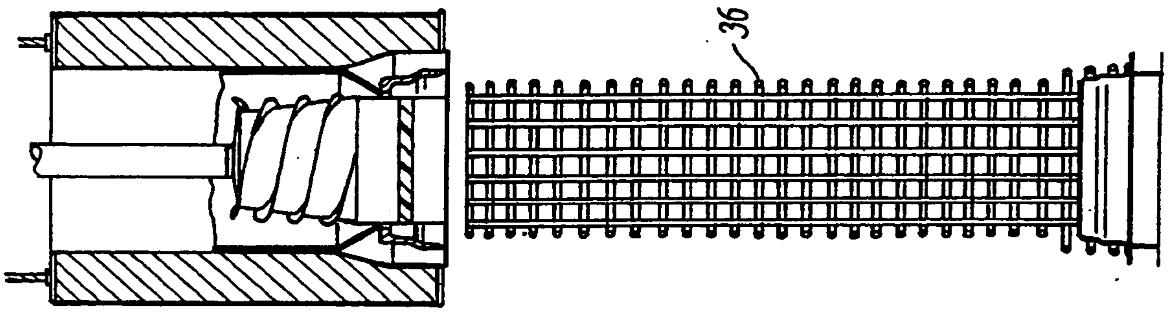

FIG.6o

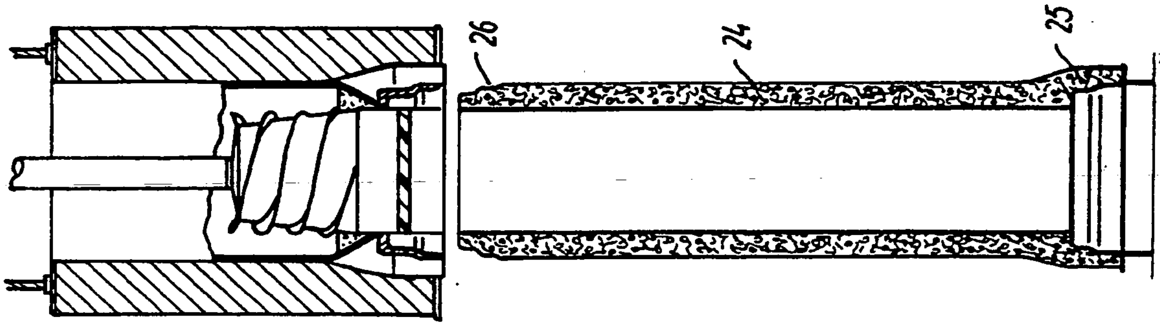

FIG.6n

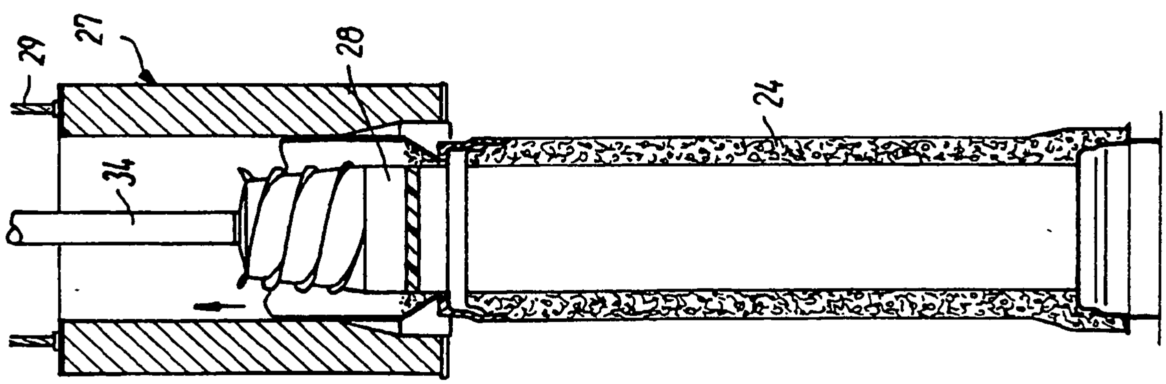

FIG.6m

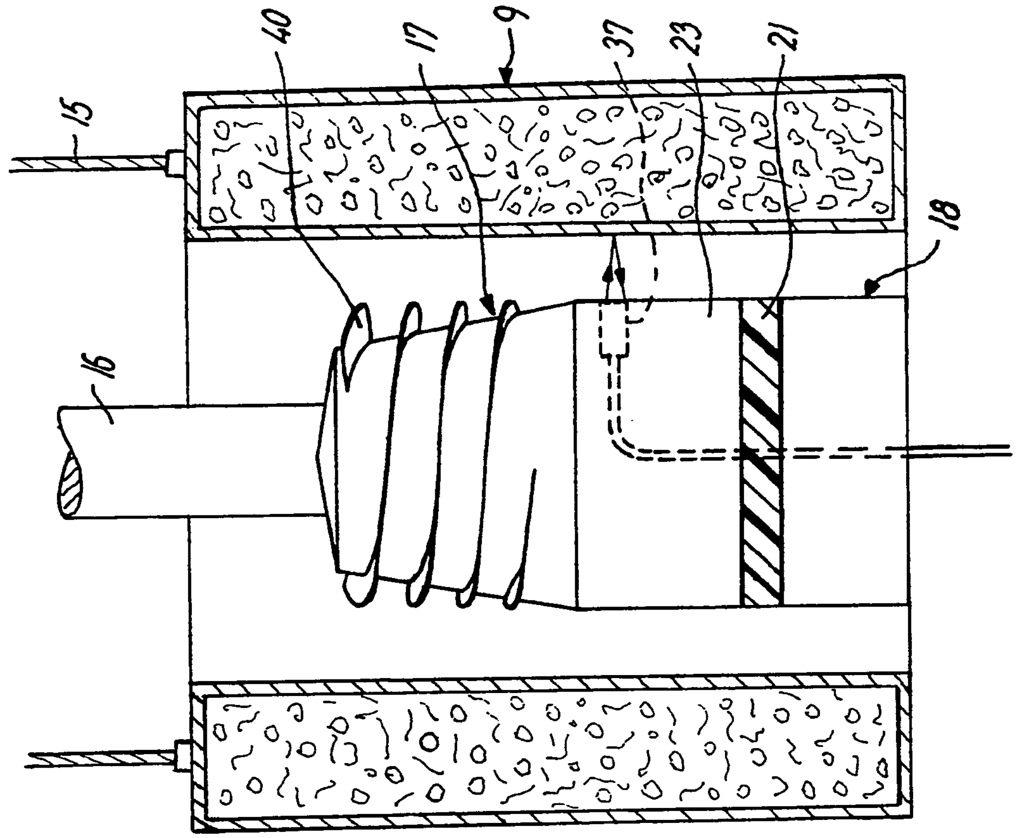

FIG. 8

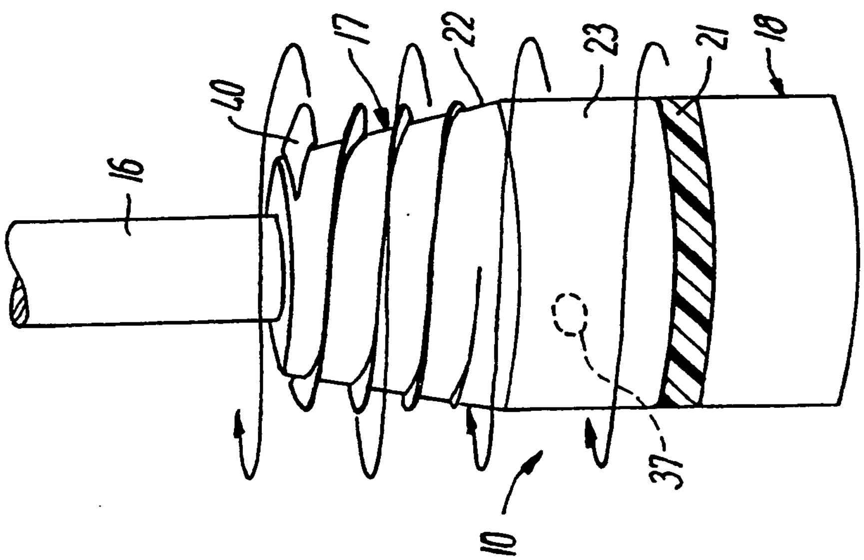

FIG. 7

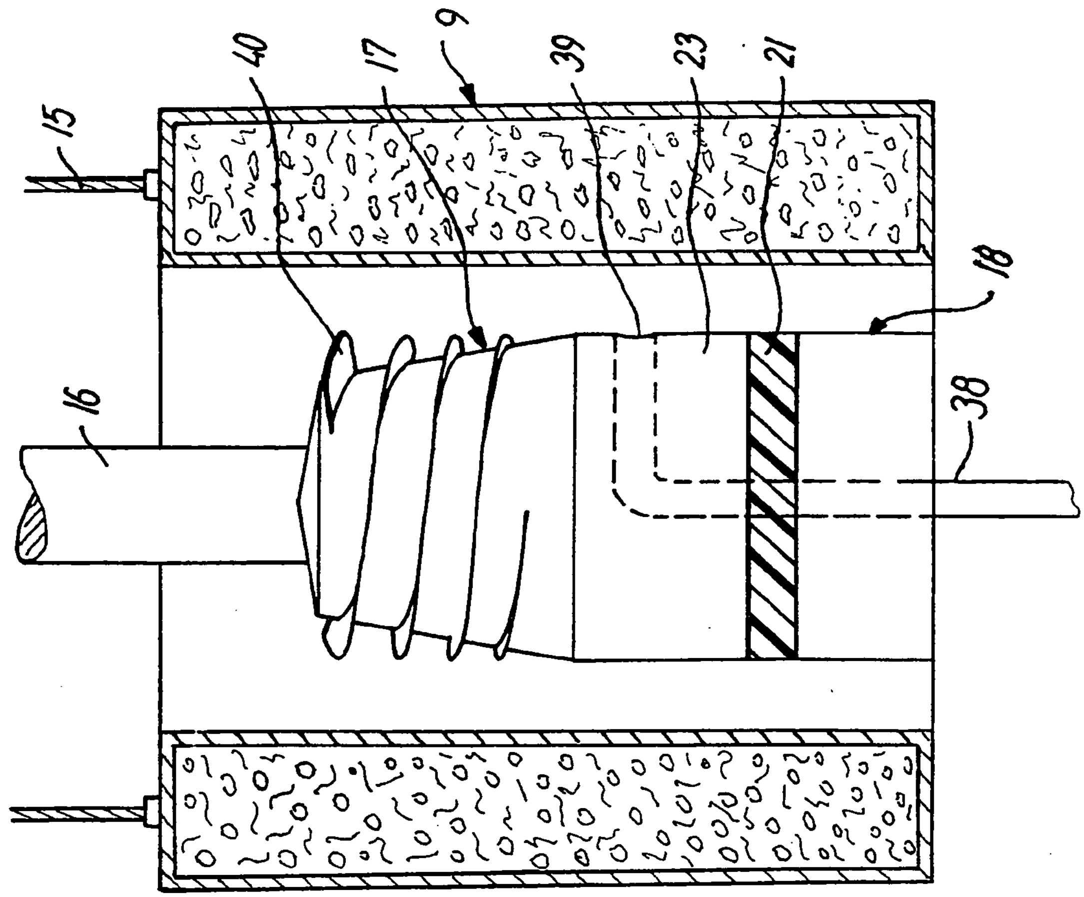

FIG. 10

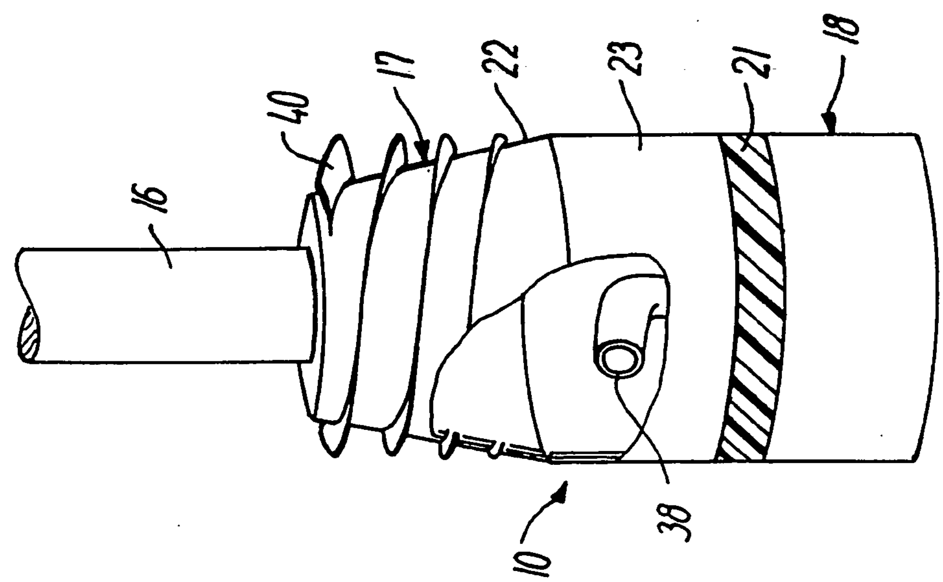

FIG. 9

INTERNATIONAL SEARCH REPORT

International Application No PCT/DK 92/00127

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all)[6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC5: B 28 B 21/14, 21/28

II. FIELDS SEARCHED

Minimum Documentation Searched[7]

Classification System	Classification Symbols
IPC5	B 28 B

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in Fields Searched[8]

SE,DK,FI,NO classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT[9]

Category *	Citation of Document,[11] with indication, where appropriate, of the relevant passages[12]	Relevant to Claim No.[13]
Y	DE, C, 864146 (H. HEETKAMP ET AL) 22 January 1953, see figure 1 --	1
Y	DE, C, 882667 (L. BÖLKOW) 9 July 1953, see figure 1 --	1
A	EP, A2, 0295938 (PARMA OY) 21 December 1988, see figure 1 detail 6 --	
A	EP, A1, 0406612 (CROCI MARIO & FIGLI S.R.L.L.) 9 January 1991, see figure 1 detail 7 --	

* Special categories of cited documents:[10]

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance, the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance, the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
13th July 1992	1992 -07- 15
International Searching Authority	**Signature of Authorized Officer**
SWEDISH PATENT OFFICE	Vilho Juvonen Vilho Juvonen

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)

Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 1813772 (A.W. SCHULTZ) 7 July 1931, see figure 1 --	
A	US, A, 3201843 (P.L. OSWEILER) 24 August 1965, see figure 1 details 49, 50 and 73 --	

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.PCT/DK 92/00127

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the Swedish Patent Office EDP file on 29/05/92
The Swedish Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-C- 864146	53-01-22	NONE	
DE-C- 882667	53-07-09	NONE	
EP-A2- 0295938	88-12-21	US-A- 4883416	89-11-28
EP-A1- 0406612	91-01-09	NONE	
US-A- 1813772	31-07-07	NONE	
US-A- 3201843	65-08-24	NONE	